



**DARPA Air-Coupled Acoustic Sensors Workshop**  
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# **Novel Parametric-effect MEMS Amplifiers/Transducers for Sonar Applications**

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## Report Documentation Page

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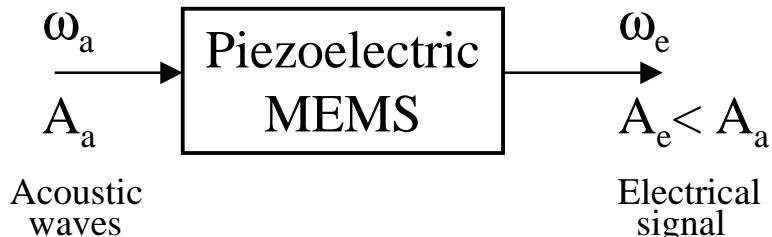
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## Idea: Use Parametric Effects in MEMS

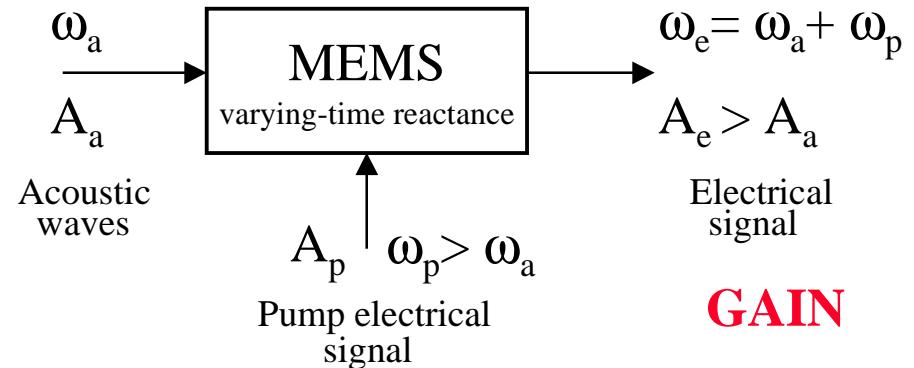


### Transducer



**LOSSES**

### Parametric Amplifier Transducer



**GAIN**

First mechanical parametric amplifier using MEMS

Advantages:

- gain at the transducer level
- low-noise (no 1/f noise)
- silicon technology: high integration, low cost
- wide bandwidth (kHz - MHz)



## Parametric Effects



- have been largely used in **1960's**: up and down frequency conversion, amplification **at microwave frequencies**.
- are based on **time varying properties** of a capacitor or inductor (Manley-Rowe Equations).
- allow to **transfer power** from the pump frequency ( $\omega_p$ ) to the input signal frequency ( $\omega_s$ ) or to the up-conversion frequency ( $\omega_u$ )  $\Rightarrow$  **GAIN**.
- The source of power for a usual transducer amplifier is a **dc supply**,  
for a parametric amplifier: the **source of power is the pump electrical signal ( $\omega_p$ ), which is a higher frequency** than the input signal ( $\omega_s$ ) .



## Amplifiers / up-converters Gain - Bandwidth



Time varying capacitor:  $C(t) = C_0 + C_1 \cos(\omega_p t) + C_2 \cos(2\omega_p t) + \dots$  with  $C_1/C_0 = 0.5 - 1.0$

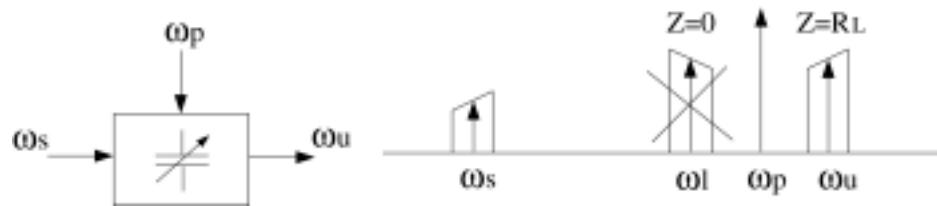
⇒ currents and voltages are generated at all combination frequencies:

$$f_{n,m} = n.f_s \pm m.f_p \quad (n,m = -\infty \dots \infty)$$

Practically, we will keep only certain combinations of frequencies.

Noninverting up-converter

$$f_u = f_p + f_s$$



Equivalent input conductance is positive  
⇒ **Stable** amplifier and possible matching

Max. gain and bandwidth at matched conditions:

$$g_u = g_s = 2\pi C_1 \cdot \sqrt{f_s \cdot (f_p + f_s)}$$

$$\text{Manley and Rowe: } \frac{P_s}{f_s} + \frac{P_u}{f_u} = 0$$

**Transducer and Power Gain:**  $\frac{P_u}{P_s} = \frac{f_p + f_s}{f_s} > 1$

**Bandwidth:**  $B = \frac{C_1}{C_0} \cdot \sqrt{2.f_s.(f_p + f_s)}$